AFRL-RH-WP-TP-2008-0005

Animated Pedagogical Agents in Interactive Learning Environment: The Future of Air Force Training?

Christopher K. Curtis
Krystal M. Thomas

Logistics Readiness Branch
Air Force Research Laboratory

Curtis H. Casteel

Signature Modeling Branch
Air Force Research Laboratory

February 2008

Interim Report for October 2006 to February 2008

NOTICE

Using Government drawings, specifications, or other data included in this document for any purpose other than Government procurement does not in any way obligate the U.S. Government. The fact that the Government formulated or supplied the drawings, specifications, or other data does not license the holder or any other person or corporation; or convey any rights or permission to manufacture, use, or sell any patented invention that may relate to them.

This report was cleared for public release by the Air Force Research Laboratory, 88th Air Base Wing Public Affairs Office and is available to the general public, including foreign nationals. Copies may be obtained from the Defense Technical Information Center (DTIC) (http://www.dtic.mil).

THIS REPORT HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

AFRL-RH-WP-TP-2008-0005

//SIGNED//
CHRISTOPHER K. CURTIS
Program Manager
Logistics Readiness Branch

//SIGNED//
DANIEL R. WALKER, Colonel, USAF
Chief, Warfighter Readiness Research Division
Human Effectiveness Directorate
Air Force Research Laboratory

This report is published in the interest of scientific and technical information exchange, and its publication does not constitute the Government's approval or disapproval of its ideas or findings.

REPORT DOCUMENTATION PAGE				*Form Approved* *OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**				

1. REPORT DATE *(DD-MM-YYYY)* February 2008	2. REPORT TYPE Interim		3. DATES COVERED *(From - To)* October 2006 – February 2008	

4.TITLE AND SUBTITLE	5a. CONTRACT NUMBER In-House
Animated Pedagogical Agents in Interactive Learning Environment: The Future of Air Force Training?	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER 62202F
6. AUTHOR(S) [1]Christopher K. Curtis, [1]Krystal M. Thomas, [2]Curtis H. Casteel	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER 7184D204

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) [1]Logistics Readiness Branch (RHAL) [2]Signature Modeling Branch (RYAS)	8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Materiel Command Air Force Research Laboratory Human Effectiveness Directorate Warfighter Readiness Research Division Logistics Readiness Branch Wright-Patterson AFB OH 45433-7604	10. SPONSOR/MONITOR'S ACRONYM(S) AFRL/RHAL
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-RH-WP-TP-2008-0005

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

88th ABW/PA cleared on 20 May 2008, WPAFB-08-3323

14. ABSTRACT

This paper looks at recent applications, empirical studies, and technical challenges in using animated pedagogical agents to deliver technical training.

15. SUBJECT TERMS
Pedagogical Agents, Interactive Learning, Training

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Christopher K. Curtis
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED	SAR	28	19b. TELEPHONE NUMBER *(include area code)*

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

THIS PAGE LEFT INTENTIONALLY BLANK

Summary

Force reductions, high operational tempos, and consolidations of career fields are prompting the United States Air Force to seek more efficient and effective ways to train the force in order to assure mission readiness. One innovative way to deliver technical training would be the use of animated pedagogical agents within interactive learning environments. This paper looks at recent applications, empirical studies, and technical challenges in using such agents for training and lays out a research plan to acquire empirical knowledge of the technology's effectiveness and limitations.

Background

Over the last 40 years, Air Force aircraft maintenance career fields have undergone numerous consolidations, generalizations, and force reductions. For example, the current "Avionics" Air Force Specialty Code (AFSC) was once seven separate career fields that included Navigation, Communications, Electronic Counter Measures (ECM), Inertial Navigation, Weapons Control, Instruments, and Flight Control. These career fields were non-weapon specific, but highly specialized requiring 42 to 50 weeks of schoolhouse training. As the AFSC mergers took place, the resulting combined AFSC career fields became less technically specialized and focused on specific weapon systems. Today, the seven career fields are combined into a single Avionics AFSC requiring only 23 weeks of schoolhouse training (Botello, Jernigan, Stimson, Marquardt, Kancler, Curtis, Barthol, Burneka, & Whited, 2006). During this same time period, the age of weapon systems being maintained has increased, spurring more frequent failures as well as different modes of failure (i.e., intermittent failures due to cracking wiring harnesses). Operational tempo has also increased as the Air Force has embarked on a series of

operations over the last 17 years starting with Desert Shield/Desert Storm and continuing on with the Global War on Terror (GWOT) along with various humanitarian missions (Moseley, 2007). The bottom line can be summarized as follows: Aircraft maintenance technicians today receive less training, are less specialized, and require more on-the-job-training at their first assignment. The force reductions and high operational tempos mentioned above aggravate this state of affairs through expert attrition and heavy daily workloads (Botello et al., 2006).

The consolidation of career fields shifting maintenance technicians from specialists to generalists falls in line with today's Air Force goal of a lighter, leaner, agile force that can respond to contingencies anywhere and anytime. However, to assure mission success, more efficient and effective ways to train technicians of all career fields are needed. The emphasis here is on using innovative technologies that can help in reducing the cost and time of training while increasing the effectiveness of training.

Extensive literature reviews have illuminated an inherent need for job training aids to provide interactive detailed instructions on performing complex tasks that are either new to the trainee or infrequent enough to prevent user proficiency. The training aid must possess universal access to relevant training materials whenever and wherever needed. Today, training is accomplished through schoolhouse coursework coupled with live instructors demonstrating proper procedures and then monitoring progress of the student in accomplishing the lesson. With the emergence of virtual reality and computer graphics systems, it is possible that some of this live training may be augmented by a virtual (computer-generated) human maintainer also known as an avatar who performs or guides the required tasks. The literature refers to these avatars and the virtual worlds they

inhabit as animated pedagogical agents and interactive learning environments, respectively. Avatars are used extensively in computer gaming for both off-line and on-line games. This gaming environment may prove to provide a significant advantage over traditional forms and methods of training for the "digital natives," (Prensky, 2001$_a$) a term used to describe the generation of people who grew up with computers, entering the Air Force today. By mimicking the environment used in games for entertainment, students may become more engaged and enthusiastic to learn.

Applications

The Army Research Development and Engineering Command in Orlando, Florida, and Forterra Inc. in San Mateo, California, have developed a multiplayer online role-playing game (called Asymmetric Warfare Virtual Training Technology or AW-VTT) which will expose soldiers to people of different cultures. The goal of the game's development is to make soldiers think critically about their surroundings and enhance their situational awareness. The game is set up to continuously operate 24 hours a day and allow participants to venture in and out of scenarios as they choose. A highlight of the system is that both deployed and soon-to-be deployed soldiers can play the game simultaneously, allowing deployed soldiers to impart their knowledge to those without the experience. A few of the roles which participants can play include civilians, insurgents, and national guardsmen. A soldier's avatar can also take on his/her physical characteristics. A soldier's physical qualification scores can be fed into the game enabling the avatar to have the same physical limitations/strengths as the person in real life. Although half complete, AW-VTT was advanced enough to be played with the Illinois National Guard Artillery Battalion. The group had no deployment experience and

the AW-VTT exposed them to cultural differences and possible hostile occurrences at simulated checkpoint operations (Peck, 2005).

The Army has also worked with Will Interactive to develop digital game-based learning systems to encourage individuals to think as teams. The Army saw that teams were not pulling together in crisis situations and gaming might be a solution. The company developed *Saving Sergeant Pabletti* which is used by over 80,000 soldiers a year to practice team skills. Drill sergeants can use the interactive game with up to 300 persons at a time. In addition to team skills, other training goals were included such as sexual harassment prevention, army values, equal opportunity, and cross cultural communication. From the use of this digital learning system, the Army saw training hours reduced from 15 hours to 4 hours (Prensky, 2001b).

The Navy, as well as the Army, conducts as much training as possible through simulated means. In 1991, the Chief of Navy Technical Training asked Dr. Henry Halff, a research psychologist, to develop a computer game for basic electricity and electronics training for avionics technicians. Dr. Halff knew traditional education was limited in terms of providing opportunities to practice newly acquired skills and constant motivation. From this, he thought adventure gaming might be an effective mode of instruction. Halff and his team created the *Electro Adventure* game. The program combined adventure gaming and traditional computer based training elements to allow the participants to discover technical and safety problems in a ship's compartment in a given scenario (Prensky, 2001b).

The Air Force has also looked at computer gaming through its development of *Falcon 4.0*, a commercially developed game. The game is a low cost simulator that

allows pilots to practice their skills during deployments. This enables the Air Force pilots

to maintain their proficiency. Even the Marines are looking at adapting commercially

available games for training. The commercial game, *Doom*, has been used to teach

teamwork, communication, and command and control concepts rather than just shooting

and killing. It is played as a networked game where four member teams, each with a

computer, play through a combat training scenario. Sound effects through the game and

participant communication add to player's confusion and disorder. Players enhance their

skills of strategy and tactics as they advance through the game and destroy the enemy

(Prensky, 2001$_b$).

Bromwich (2007) mentions that one of first corporate dealings with avatars

included *Clippy*, the animated paperclip of Microsoft Office. This avatar, for the most

part, was an annoying office assistant which would appear in the bottom corner of one's

computer screen and offer help in word processing. Since then, avatars have come a long

way in the workplace. CDW Corporation, a technology products and services company,

sought development of a sales training course for their employees through Accenture Ltd.

In the course, avatars were to take on the persona of coaches and guide the trainees

through mock interactions with varied-response customers. Bromwich reports from Bruce

Damer, author of <u>Avatars! Exploring and Building Virtual Worlds on the Internet</u>, two

examples of avatar technology use in industry. Boeing, he points out, has used avatars in

a virtual Super-jumbo Plant to resolve issues with the giant Airbus. The avatars can take

on an insect view of the plane and see fine details. Once a problem is discovered, the

avatars disappear and the experience is recorded for future analysis. In addition, EDS

used a virtual avatar to "conduct weekly classes for EDS employees worldwide" which aided the company in "corporate problem solving and training" (Bromwich, 2007).

Avatars in virtual worlds have also been applied to medical education with possibilities in individual learning, team training, and complex team training. The SUMMIT development team at Stanford University has designed a web-based 3D virtual world for medical purposes in chemical, biological, radiological/nuclear, and explosive (CBRNE) incidents. Multiple players access the world for training with an emphasis on interactions betweens team members. The virtual world is not appropriate for procedural skills (say insertion of a needle) like it is for participant training in leadership, communication, and team training. In this simulation-based learning, individual learners control avatars in a 3D world where a CBRNE event has occurred. Participants can also be dispersed. Learners interact with the simulated victims, as well as one another, while their instructor oversees the exercises. The training is usually followed up with an after-action review or debriefing with the instructor and participants to review items that worked well and items which could have been performed differently (Dev, Youngblood, Heinrichs, & Kusumoto, 2007).

Empirical Studies

Since the application of avatars in training environments is still relatively new, very little empirical knowledge exists as to their effectiveness in these environments. While technology is getting better at providing more realistic representations of human characteristics and enabling more natural communication between the student and avatar, we still do not know how effective the technology is for achieving training goals or

where it would be best to apply the technology. Johnson, Rickel, and Lester (2000) report on two empirical studies of animated pedagogical agents.

The first study was conducted on the *Herman the Bug* agent that inhabits the *Design-A-Plant* learning environment. *Design-A-Plant* is a design-centered learning environment where students explore the physiological and environmental factors that determine the survival of a particular plant design. The purpose of this experiment was to obtain a baseline of the potential effectiveness of animated pedagogical agents on problem solving and study the effects of different levels of interaction employed by the animated pedagogical agents. The study involved one hundred middle school students, each interacting with one of five versions of the *Herman the Bug* agent. The versions differed based on modes of expression and the level of advice they offered with respect to the students' problem solving activities. The five versions are listed as follows:

- **Muted**: This version provided no advice at all and was used as an experimental control

- **Task-Specific Verbal**: This version provided only task-specific (low-level) verbal advice

- **Principle-Based Verbal**: This version provided only principle-based (high-level) verbal advice

- **Principle-Based Animated/Verbal**: This version provided principle-based advice using both animated and verbal responses.

- **Fully Expressive**: This version provided both principle-based and task-specific advice using both animated and verbal responses.

The learning environment captured all interactions during the problem solving activities. The students were given a pre-test and post-test to measure baseline knowledge and improvement. The results were as follows:

- Students interacting with animated pedagogical agents showed statistically significant increases in knowledge from pre-test to post-test, thus establishing that a well designed virtual learning environment can successfully transfer knowledge.

- Animated pedagogical agents that employed multiple levels of advice and multiple modes of providing that advice yielded greater improvements on post-tests than less expressive agents, demonstrating higher benefits in using multimodal agents that provide both theoretical and practical advice.

- Positive effects of animated pedagogical agents were more pronounced when students dealt with more complex problems, indicating the potential effectiveness of agents in assisting students in solving complex technical problems (Lester, Converse, Stone, Kahler, & Barlow, 1997).

The second study cited involved the German Research Center for Artificial Intelligence that conducted an experiment to evaluate the effectiveness of the *Personalized Plan-Based Presenter (PPP)* agent in facilitating learning. Two versions of a learning environment were created. One used the *PPP* agent to point out specific areas of interest. The other did not use the *PPP* agent, but instead used simple arrows to identify specific items. Both used the exact same narration. The test subject pool

consisted of 30 adult participants (15 female and 15 male) recruited from Saarbrucken University. The test subjects were asked to view two types of presentations. One type was a technical description of different pulley systems and the other was a non-technical description of fictitious office employees (Johnson et al., 2000). Unlike the *Design-A-Plant* experiment, the subjects did not have to do any problem solving. The learning effect was measured through questions of comprehension and recall following the presentations. Qualitative data was also collected through a questionnaire at the end of the experiment.

The results of this study showed that there were no differences between the test subjects' comprehension of the information presented based on the presence of the *PPP* agent. However, the qualitative data gathered indicated that most of the test subjects preferred the presentations with the *PPP* agent. Also, most subjects stated that the technical presentations were easier to understand and more entertaining with the *PPP* agent (Andre, Rist, & Muller, 1999).

There have been other studies looking at the effects of animated pedagogical agents where learning was affected. Atkinson (2002) performed two experiments which looked at incorporating pedagogical agents in a computer-based environment to teach learners to solve word problems. In the first experiment, two questions were asked:

- Are examples coupled with pedagogical agents more effective at promoting learning than examples without the agent present?
- Are examples containing aural or textual explanations (both paired with an agent) more effective at promoting learning?

With this, the author set out to design a study where 50 undergraduate students from the Educational Psychology and Psychology Departments at Mississippi State University were used. Students were randomly assigned to five conditions: voice-plus-agent, text-plus-agent, voice only, text only, or control (where no instructional explanation or agent was present). Participants participated in two sessions. A pre-test and post-test were used to measure information transfer and a five-point Likert scale questionnaire was used to measure reported example difficulty. Voice conditions (voice-plus-agent and voice only) were found to have a significant effect on reported example difficulty. Participants exposed to the voice conditions had less difficulty in solving word problems than those presented with text-based explanations. Those presented with voice also outperformed those exposed to text explanations in transfer scores (Atkinson, 2002).

From the first experiment, the author learned that low power resulting from the number of participants in the experiment negatively affected the statistics. Therefore, for the second experiment, the two sessions were collapsed into one session. Also, the reliability of the post-test was improved by adding more items and two conditions were removed leaving: voice-plus-agent, voice only, and text only. Here, the following questions were asked:

- Are examples paired with visual and auditory presence of agents more effective at promoting learning than in text only examples?
- Are examples paired with visual and auditory presence of agents more effective at promoting learning than in voice only examples?

Seventy-five undergraduate students from the same university participated in the second experiment while being randomly assigned to one of the three conditions. The same measures were carried over to this experiment. The three conditions statistically differed from one another for example difficulty. The participants in the voice-plus-agent condition outperformed those in the text only condition. Also, for transfer information, students in the voice-plus-agent condition performed superior to those in both the voice only condition and text only condition. It was shown from both experiments that pedagogical agents presented along with aural capabilities can help optimize student learning (Atkinson, 2002).

A study investigating computer-based learning for students was conducted via two experiments. The major difference in the two experiments was the pool of subjects used (the first used college students whereas the second used seventh grade students). Students were taught how to design the roots, stems, and leaves of plants to mature in various environments (Moreno, Mayer, Spires, Hiller, & Lester, 2001).

The first experiment was to determine whether pedagogical agents helped students in their deep learning of the social agency environment more than information presented with text on-screen. The measure of deep learning was defined as a student's ability to rely on previous knowledge of a subject matter to create mental models which would aid in problem solving. From a psychology subject pool at the University of California, Santa Barbara, 44 students participated. Subjects were randomly assigned to two conditions including PA (aural pedagogical agent) or No PA (text only information). Retention, transfer, and interest were measured through post retention tests, post

problem-solving tests, and ten-point rating scales, respectively. For retention, students

learning with the aid of a PA did not statistically differ in their retention from those in the

No PA condition. In effects on transfer, students in the PA condition produced

significantly more correct answers than those in the No PA condition. Those introduced

to the PA also significantly produced more correct answers on difficult transfer problems

than the No PA group. Effects on student interest of the material showed that the PA

group rated a significantly greater interest of the material than did the No PA group.

Also, students in the PA group significantly had stronger interest in continuing

instruction in their program versus the No PA group. The first experiment was replicated

on a younger set of seventh-grade students in a second experiment with consistent results

over both student populations. That is, the presence of a pedagogical agent positively

affects students' deep learning of information. In addition, students reported more interest

in a social agency environment (one with the PA) rather than the text only presentation

environment (Moreno et al., 2001).

Finally, another study looked at an agent, *AutoTutor*, and measured its effects on

deep learning and shallow learning (Graesser, Moreno, Marineau, Adcock, Olney, &

Person, 2003). The authors defined deep learning as the understanding of consequences

of events and deriving methods for problem solving, whereas shallow learning consisted

of basic information in a field relating to definitions, properties, and examples of

technical components. The agent uses natural language to communicate to students. In

this experiment, the authors sought to find whether dialog presentation of information or

the media presentation of information was what facilitated learning. Eighty-one students

participated in a study to become computer literate (hardware, operating systems, and

internet). *AutoTutor* could be accompanied by any of the combinations: print (text) only, speech only, agent with speech, and agent with speech and text. In all, four conditions were presented to the students. Pre-test and post-test were given to assess the students' deep and shallow knowledge. Results showed significant effects of training on deep scores rather than shallow scores where the *AutoTutor* agent was present. All versions of *AutoTutor* were superior in improved deep learning versus instances without the agent present.

Technical challenges

As with any software environment, there are technical issues associated with intelligent tutoring systems as well as interactive learning environments. Some of the major issues revolve around representing and reasoning about domain knowledge, modeling and adaptation to user's knowledge, choosing appropriate pedagogical strategies, and maintaining a coherent and understandable dialogue.

Virtual reality (VR) is a user interface paradigm in which the user feels immersed in a computer-generated space, whereas a virtual world describes virtual reality systems that allow multiple users to interact in the same space. The virtual world is a three-dimensional representation of an environment that the user operates. Due to the multiple networking of clients, there are several technical problems associated with databases required to support a multi-user VR system. Applications currently being explored by commercial industry include research at Microsoft. This research has explored an object-oriented multi-user world in which a network database server stores objects having properties and methods. Room objects, representing discrete locations, interconnected by portal objects with each room having a descriptive text, which users read to situate

themselves in the location, define the topology of the space. Also, objects can represent things located in a room and objects called "players" or "avatars" represent a user's character in the virtual world (Vellon, Marple, Mitchell, & Drucker, 1997).

Programming behavior in virtual worlds is accomplished by defining methods on objects in the environment. In the basic object model, a few basic objects are provided such as "Rooms," "Portals," "Artifacts," and "Avatars." An Avatar has a variety of properties and methods to specify the object representing the user in the world. Some of these properties include the gender of the avatar, a list of friends, the room, and user information (Vellon et al., 1997).

An animated pedagogical agent's environment consists of the learning environment, the user, and any other agents in the learning environment. In order to understand the inner workings of such agents, it is necessary to discuss the interface between the agent and the pedagogical environment. The interface is divided into two parts consisting of the agent's awareness of the environment, or perception, and its ability to affect the environment, or motor actions. One of the primary motivations for animated pedagogical agents is to expand the bandwidth of human-computer interaction, thus their perception and motor actions are typically more diverse than previous computer tutors and learning companions (Johnson et al., 2000).

Most animated pedagogical agents track the state of the problem that the user is addressing. Other agents track more unusual events in their environment such as speech events, location within the environment, visual attention, gestures, and interaction between an agent's body and its environment. Current advanced research may focus on other features such as a user's facial expressions and emotions. These advanced and

multiple states add to an already difficult database to address and process the agents of a virtual world. Interactions between an agent's body and its environment require spatial knowledge of the environment being used. This is one of the key motivations for animated pedagogical agents that include the ability to look at objects, point to them, demonstrate how to manipulate them and navigate around them. This is important for any future learning environment for both the teacher and the user. To date, relatively simple representations of spatial knowledge have allowed animated pedagogical agents to accomplish their needs. These simple representations include task bars and bitmap images that allow the agents to quickly conduct activities such as locomotion to include walking, sitting, and standing as well as gestures and behaviors. However, these are just the simple problems associated with navigating in a virtual world (Johnson et al., 2000).

Complex algorithms must be utilized in order to avoid collisions between users and their environments to include other users. It is critical that control points, the coordinates to be navigated, be interpolated in a manner that (1) enables the agent's movement to appear smooth and continuous and (2) guarantees retaining the collision-free property. To accomplish this natural behavior, the navigation planner generates a Bezier spline that interpolates the discretized path from the agent's current location, through each successive control point, to the target destination (Johnson et al., 2000).

To affect their environment, pedagogical agents require a vast repertoire of motor actions. These actions fall into speech, body control, and learning environment control. Typically, speech is generated as a text string to allow one agent to speak to another and may be displayed as text or processed through a speech synthesizer. Body control may involve playing animation clips for the entire body or specific segments for gestures,

expressions, and locomotion. Environment control may include changing background music, environment background or scenery, and responses to object manipulation such as the response from pushing a button. These actions formulate the behavioral building blocks of the virtual world and learning environment (Johnson et al., 2000).

In order to design the behavior of an agent, the building blocks of an agent's behavior must be generated along with the code that will select and combine the right building blocks in order to respond correctly to the situation. The most common method for generating behavior of a pedagogical agent is the behavior space approach. A behavior space is a library of behavior fragments and is generated by dynamically stringing behavior fragments together at runtime. Creating these behavioral fragments can range from the simple to extremely sophisticated depending on the desired state of animation. In order to select the appropriate behavior at runtime, each behavior fragment must be associated with additional information that describes its content. This is accomplished through the use of ontological, intentional, and rhetorical indexes. Ontological indexes are used for explanatory behaviors, intentional indexes for advisory behaviors, and rhetorical indexes for audio segments. This building block approach provides very high quality animations but is limited because designers must anticipate all of the behavior segments and develop complicated rules for assembling them together (Johnson et al., 2000).

Alternatives to the behavioral space approach include generating behavior dynamically as well as controlling behavior. Flexibility is achieved by generating behavior as it is needed without using any previously saved animated segments or individual frames as is the case in the behavioral space method. However, using dynamic

behavior that is generated on the spot includes tradeoffs such as decreased quality of images and fragmented speech due to real-time data processing. Stored images and sound clips of behavior space modeling eliminates the quality issue but is constrained to delivering only the behaviors stored in a database. Behavior control includes the use of pedagogical context, task context, and dialogue context. Respectively, this includes the instructional goals and a model of the student's knowledge, the state of the users and agent's problem solving, and the state of the collaborative interaction between the user and the agent (Johnson et al., 2000). Ideally, a combination of using stored data from the behavior space as well as processing on the spot new behavior from dynamic behavior or behavior control would work much better. The main obstacle is overcoming and controlling the behavior of an animated agent by synchronizing its nonverbal actions with its verbal utterances. Overall, the primary goal is for the interactive environment to be believable. By creating the illusion of life, dynamically animated agents have the potential to increase the amount of time users spend with educational software (Johnson et al., 2000). Moreover, increased technological advances have made graphics hardware more affordable and the widespread distribution of real-time animation technology a reality.

One of the current virtual worlds created that has addressed several of the aforementioned technical difficulties is the Internet based *Second Life* program that was launched in 2003 (Sege, 2006). *Second Life* was developed by Linden Research, Inc., and enables users to interact within a social network in a virtual environment. Avatars are used to identify users and communication is made available through local chat and instant messaging. Locomotion is available in the forms of walking, jumping, flying, as well as

riding in vehicles and teleportation to a specific location. Current technical obstacles

include the database engine freezing due to severe load conditions by users. These

overloads may cause objects to disappear unexpectedly, searches to fail, or total system

shut down. Linden addressed these issues along with a primary problem known as the

Deep Think condition with its Havok 4 physics engine. The Deep Think problem is

encountered when two physical objects intersect one another in the virtual world and the

engine does not know how to separate the objects. Thus, the program goes into a

recursive loop trying to analyze the overlapping objects and eventually consumes all

available CPU power and reduces the simulator to a crawl. Linden addressed the physics

based problem by creating an overlap ejection capability that allows overlapped objects

to separate and propel apart just as in compressing two springs against each other. To

address the scripting problems and help make the user experience more pleasant, Linden

has developed the LSL scripting language that is similar to C. Basically, LSL determines

the behavior of objects using a combination of primitive shapes, or "prims" which are

sized, scaled, and stretched as needed, with images, called "textures," applied to the

surface of the prim to alter its appearance. LSL determines how the objects behave,

controlling the waving of virtual hair, driving a vehicle, or other animated object.

Everything in *Second Life* is composed of some combination of prims, textures, and LSL

scripts (Greenemeier, 2005).

     Currently, *Second Life* is innovating Internet use and is clearly in the early stages

of the design process. However, growth escalated from 18,000 in Dec 2006 to 36,000

users in March 2007 and is currently estimated to have over 1 million users. To handle

such an enormous computational burden, *Second Life* runs on 2,000 Intel processors in

two co-located facilities in San Francisco and Dallas where the servers support over 34 terabytes of user created content (Wagner, 2007). Aside from the virtual social network, Linden is exploring the virtual education environment. *Second Life* has recently become one of the cutting edge virtual classrooms for major colleges and universities. Universities such as Harvard, Princeton, and Vassar have already begun teaching using *Second Life* as a 3D computer program to host interactive learning. Universities are able to buy land within *Second Life* for educational purposes and block access from outsiders. This capability has eliminated a cost burden for developing new training programs and tools for education. Likewise, the interactive and virtual environment catches the user's or student's attention and makes learning fun. Selective areas chosen for lessons allow for advanced learning such as philosophy seminars in a Japanese Zen garden (Parker, 2007).

However, *Second Life* is not without its problems. Since the virtual world is created through programming language, there are security risks. One area of concern for parents is online stalking and sexual predators that may be lurking in the virtual world. Also, advanced users may hack into holes in the source code where they can alter other users' avatars and activities such as disabling their movement (Lagorio, 2007). Also, malicious users may disrupt user environments by destroying scenery or simply leaving thousands of items on the ground in the form of cyber littering which all that enter the environment will see. It is clear that Linden and *Second Life* are in the early stages of the design process. No dominant design has occurred and current development is at the low end of Foster's S-curve (Utterback, 1996). Due to the lack of a dominant design, there exists the potential for a competitor to enter the virtual world against Linden and disrupt

its current technological advancement of the Internet along with the virtual education market.

Way ahead

As the technical challenges become settled and a dominant design emerges, it would seem reasonable that the application of animated pedagogical agents and their associated interactive learning environments would only increase. In fact, Air Education and Training Command (AETC) has expressed interest in using avatars in virtual Air Force bases for training similar to Linden's *Second Life* in their White Paper <u>On Learning: the Future of Air Force Education and Training</u> (2008). In light of this expansion of various training applications, empirical studies probing into the technology effectiveness for Air Force training are critical in assessing return on investment. What follows is a deliberate method of research that the Logistics Readiness Branch of the Air Force Research Laboratory's Human Effectiveness Directorate is currently executing through the Maintenance Aiding and Training Technology Experimental Research (MATTER) effort.

Under the Advanced Visual and Instruction Systems for Maintenance Support (AVIS-MS) research project, the utility of augmented reality was investigated for the presentation of procedural instructions during maintenance tasks and the acquisition of task data from expert task performance on a real device. One of the lessons learned during this research is that obtaining human performance information from tasks involving full scale physical props remains a challenge for common motion capture technologies. These limitations have inspired further research of a new untethered motion capture technology that has matured to a point that is viable for study.

The Untethered Motion Capture Evaluation for Flightline Maintenance research project is exploring and evaluating the utility of novel motion capture technologies within the Air Force maintenance domain. A primary objective is determining the potential of untethered motion capture capabilities for real-time human subject motion capture and performance data collection with full scale physical props. Data will be collected and evaluated during a maintenance task scenario for the purpose of instruction generation and maintenance training. The effort consists of a domain analysis, a conceptual design and architecture definition, a prototype development, and a performance evaluation of motion and task matching algorithms within relevant operational maintenance scenarios. Laboratory and field research will be used to evaluate the efficacy of untethered motion capture for obtaining human performance data from tasks involving full scale physical props and the reuse of this information within augmented procedural instruction.

The Technical Instruction Multimedia Extensions for Training (TIMET) research project will investigate the selective addition of multimedia content, especially segmented video and 3D animated virtual maintainers, to existing technical instruction presentations as a training aid. The research will review available resources concerning animated virtual maintainers, identify suitable maintenance tasks that can be visualized through virtual human interfaces, prototype a virtual human interface within existing electronic technical instructions as rendered on a portable electronic device, develop semantic annotation of Computer Aided Design (CAD) models (manual labeling) for part reference during subject performance monitoring, and investigate preliminary coaching behaviors based on evaluation of subject motion capture while on task. The computer generated virtual humans will interface with CAD models of the selected maintained

systems in such a fashion that design updates to the CAD models may automatically generate plausible new animations for the virtual maintainer.

The Virtual Coaching Agent for Team Training (VCATT) research project will investigate an interactive, computer-generated, human agent to guide a subject or team of subjects during a maintenance task training scenario and measure, evaluate, and verify trainee(s) actions against an established expert model of task performance. The coach will process training task performance data from the trainees and establish when the performance appears to deviate from the current task goal. Any deviation will invoke explicit behavior by the coach to take appropriate action such as reiterate the current goal, remind the trainees about overlooked cautions and warnings, or demonstrate the correct task behavior. This research will extend previous work under the TIMET project by evaluating interaction techniques between coach and subject as well as multiple subjects working together on a team. Integration of wider knowledge sources into the coach concept such as function, physics, and geometry will yield suitable system-level understanding of the maintenance task. A field evaluation of the coaching system in an actual training environment will measure performance impacts by various team members while performing training procedures. Preliminary data will be collected on the effectiveness of the coach to reduce errors and increase training effectiveness as well as identify limitations for training applications.

The Anticipating Future Job Aiding/Training Requirements Workshop effort will evaluate overall Air Force maintenance training needs and costs versus future trends in technology development. The overall objective is to assist the Air Force Research Laboratory in identifying and defining research vectors/thrusts related to future tools,

technologies, and techniques for job aiding and training 10 to 15 years out. A small multidiscipline team of experts and visionaries in academic and professional fields related to job aiding and training have been assembled from applicable fields (e.g. educational technology, computer science, social sciences, etc.). These experts will come together and participate as part of a small working group that will help AFRL in defining job aiding and training research vectors/thrusts to address future Air Force operational requirements. The formal product from this research task is a technical report that addresses the following:

a. A survey of the future workforce in general, and Air Force specifically (e.g. demographics, skills and education, etc.)

b. An assessment of the future work environment in general, and Air Force specifically (e.g. nature of work, training requirements, etc.)

c. An assessment of current and future technologies and trends focused on improving job aiding and training (e.g. distributed learning, simulation, etc.)

d. A critical and unbiased assessment of the technology gaps and training shortfalls with respect to the above survey and assessments

e. A discussion of research streams or vectors which could be pursued in the future to address the identified technology gaps and training shortfalls

Summary

This paper provided a brief overview of the need for more innovative ways in delivering technical training to support the Air Force vision for a lighter, leaner, agile force. The paper explored animated pedagogical agents within interactive learning environments as a technology that could be exploited for portable training augmentation for the schoolhouse as well as just-in-time training for operations in the field. Several applications of virtual training applications used by the Department of Defense and commercial industry were discussed. While the applications were varied, the end goals of the training applications were similar: reduced costs, reduced time, improved communications, distributed widely, and increased appeal to a younger generation of workers. Technical challenges were discussed highlighting advantages and disadvantages of two approaches, stored and dynamic, used to program behavior of the agents. The approach used will ultimately depend on customer requirements for the application. It was noted that a dominant design has not emerged as most applications are proprietary and vertically integrated for performance. As the technological improvements exceed customer requirements, responsiveness and convenience will become the new design criteria especially as the demand for custom training applications increase. We will see more interoperability and modular designs when this happens (Christensen & Raynor, 2003). Finally, a deliberate research method was laid out in an attempt to build up empirical knowledge on the technology effectiveness and limitations for use in Air Force training. This innovative technology shows great potential for future training. To what degree is still to be determined.

References

Air Education and Training Command (White Paper). (2008). <u>On learning: the future of Air Force education and training.</u> Retrieved January 31, 2008 from http://www.aetc.af.mil/shared/media/document/AFD-080130-066.pdf

Andre, E., Rist, T., and Muller, J. (1999). Employing AI methods to control the behavior of animated interface agents. <u>Applied Artificial Intelligence,</u> 13:415-448.

Atkinson, R. K. (2002). Optimizing learning from examples using animated pedagogical agents. <u>Journal of Educational Psychology, 94(2)</u>:416-427.

Botello, C., Jernigan, J., Stimson, D., Marquardt, S., Kancler, D. E., Curtis, C. K., Barthol, D. R., Burneka, C. M., and Whited, V. T. (2006). <u>Aircraft Maintenance Intuitive Troubleshooting (AMIT),</u> AFRL-HE-WP-TR-2007-0006. Human Effectiveness Directorate, Logistics Readiness Branch, Wright-Patterson AFB, OH.

Bromwich, C. (2007, September). <u>Avatars in the workforce: All work and no play, but not for long</u>. Retrieved November 30, 2007 from http://enliten.net/docs/poe/Avatars_in_the_Workplace.pdf

Christensen, C. M., & Raynor, M. E. (2003). <u>The innovator's solution: Creating and sustaining successful growth.</u> Boston: Harvard Business School Press.

Dev, P., Youngblood, P., Heinrichs, W. L., and Kusumoto, L. (2007). Virtual worlds and team training. <u>Anesthesiology Clinics</u>, 25:321-336.

Graesser, A. C., Moreno, K., Marineau, J., Adcock, A., Olney, A., and Person, N. (2003). <u>AutoTutor improves deep learning of computer literacy: Is it the dialog or the talking head</u>. Retrieved November 30, 2007 from http://www.cs.pitt.edu/~chopin/tig/AIED-graesser-2003.pdf

Greenemeier, Larry (2005). <u>Open doors to innovation</u>. Retrieved December 7, 2007 from http://www.informationweek.com/story/showArticle.jhtml?articleID=172300923&tid=5979,5989

Johnson, W. L., Rickel, J.W., and Lester, J. C. (2000). Animated pedagogical agents: face-to-face interaction in interactive learning environments. <u>International Journal of Artificial Intelligence in Education</u>, 11:47-78.

Lagorio, Christine (2007). <u>The ultimate distance learning</u>. Retrieved December 13, 2007 from http://www.nytimes.com/2007/01/07/education/edlife/07innovation.html

Lester, J. C., Converse, S. A., Stone, B. A., Kahler, S. E., and Barlow, S. T. (1997). Animated pedagogical agents and problem-solving effectiveness: A large-scale empirical evaluation. Proceedings of the Eight World Conference on Artificial Intelligence in Education, pp. 23-30.

Moreno, R., Mayer, R. E., Spires, H. A., and Lester, J. C. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? Cognition and Instruction, 19(2):177-213.

Moseley, M. T. (2007) The nation's guardians: America's 21st century Air Force. [CSAF White Paper] Retrieved January 31, 2008 from https://www.my.af.mil/gcss-af/USAF/AFP40/d/1074676447/Files/editorial/CSAFStrategyWhitePaper.pdf

Parker, Quin (2007). A second look at school life. Retrieved December 7, 2007 from http://education.guardian.co.uk/elearning/story/0,,2051195,00.html

Peck, M. (2005, February). Soldiers learn hazards of war in virtual reality. Retrieved November 30, 2007 from http://www.nationaldefensemagazine.org/issues/2005/Feb/UF-Soldiers_Learn.htm

Prensky, M. (2001a). Digital natives, digital immigrants. Retrieved October 30, 2007 from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf

Prensky, M. (2001b). True believers: Digital game-based learning in military. From book entitled: Digital Game-Based Learning. Retrieved November 30, 2007 from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Game-Based%20Learning-Ch10-Military.pdf

Sege, Irene (2006). Leading a double life. Retrieved December 3, 2007 from http://www.boston.com/news/globe/living/articles/2006/10/25/leading_a_double life/

Utterback, J. M. (1996). Mastering the dynamics of innovation. Boston: Harvard Business School Press.

Vellon, M., Marple, K., Mitchell, D., and Drucker, S. (1997). The architecture of a distributed virtual worlds system. Retrieved December 1, 2007 from http://research.microsoft.com/vwg/papers/oousenix.htm

Wagner, M. (2007). Inside Second Life's data centers. Retrieved December 7, 2007 from http://www.informationweek.com/news/showArticle.jhtml?articleID=197800179&pgno=1&queryText